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ABSTRACT

This report presents an overview of the damage to library materials caused by uncontrollable environmental variables. The control of atmospheric pollutants, temperature, and humidity are discussed with regard to damage, standards, and the costs of deterioration due to these factors. Twelve references are listed. (FM)

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ENVIRONMENTAL CONTROL FOR REGIONAL LIBRARY FACILITIES

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SUMMARY

This report gives a brief overview of the damage to library material caused by uncontrolled environmental variables. Standards for control of air pollutants, temperature and humidity are discussed. Brief discussion is then given of possible costs associated with continued or additional damage to material housed in off-campus sites. The report points out that the estimated value of materials to be housed at each Regional Facility is $281,250,000. The cost of environmental protection for this investment is estimated at $1,160,000 per facility or 1/243 of the estimated value of the material. Replacement of only 12,000 volumes owing to degradation by environmental factors would offset the capital cost of environmental control.

PROLOGUE

The chief enemies of books and other library materials are extremes of temperature and humidity, inherent acidity of paper and biological agents such as mold. Environmental control within buildings housing library collections is the most certain, and best understood, way to retard the degradation of this material. It is also probably the cheapest method of damage control for such collections. While capital costs for implementation of environmental control are estimated at forty cents per volume, repair or restoration costs for material damaged by environmental extremes are estimated at $50-$250 per volume. The following report notes the damage which can be caused by uncontrolled environmental variables as well as current standards for control. Possible costs associated with damage by environmental factors are discussed.

CONTROL OF ATMOSPHERIC POLLUTANTS

Damage caused by unfiltered air

Unfiltered air contains a variety of agents harmful to library material. These agents are of two classes: 1) particulate matter and 2) gases. In 1967, Haagen-Smit (1) reported that twenty to thirty tons of particulate matter fell per square mile per month in Los Angeles; "although Los Angeles is considered to be a comparatively clean city in this respect." By extrapolation we find that the Southern Regional Facility site might receive 1200 pounds or more of particulate matter per year from the ambient air. Such particulate matter is both abrasive and disfiguring to library materials and dust particles also serve as nuclei or catalysts of chemical reactions which degrade paper. Mold spores also constitute a fraction of this airborne particulate matter. Since publication of the Haagen-Smit article in 1967, there have been dramatic increases in particulate and gaseous pollutants in both the Los Angeles and San Francisco areas.

Unfiltered air also contains large amounts of gaseous pollutants such as, but not limited to, carbon dioxide, sulfur oxides, and oxides of nitrogen (2). Each of these compounds react with atmospheric water to form acids, i.e., carbonic, sulfuric, and nitric. These acids in turn hydrolyze the unit bonds in cellulose chains causing breakage of the chains. In practical terms this leads to embrittlement and failure of cellulose based material including paper and photographic products. These acids also similarly attack leather book bindings.

Kimberly (3) found that it took only ten days for the average printing paper to lose about 15 percent of its initial folding endurance strength when exposed to the atmospheric pollutant SO_2 gas. Book materials are permeable to gases such as SO_2 and will exhibit the same strength loss although over a longer period of time.

Standards for air filtration

The ASHRAE(4) standard for filters of particulate matter is 85 percent efficiency. This is the minimal acceptable efficiency. Proposed standards for removal of gases and odors at the Regional Facilities were developed by the architects after consultation with the staff of the Library of Congress and are not discussed in this report.

Garver (5) has described the best air filtering system as being comprised of three parts:

1) mechanical filtering for particulate matter,

2) air washing in alkaline water to eliminate oxides which form acids, and

3) adsorbent units to remove other gases and to remove odors from the recirculated air.

The recommendations for the Regional Facilities began with this type of system and were modified by the architects to meet the actual experience and recommendations of the Library of Congress.

Effects of non-filtration on library materials: estimated costs

It can be estimated that housekeeping costs at Regional Facilities would increase dramatically in the event that the incoming air remains unfiltered at the facilities. General housekeeping costs might increase by $.25/ft^2$ or $30,000 per year, per facility. A yearly vacuuming of each book would also become necessary at an estimated cost of $150,000 for 3,000,000 volumes per year.

The damage sustained by each volume, at capacity, from acid hydrolysis owing to unfiltered oxides can be estimated at $.05 to $.10 per volume, per year. At this rate, damage costs of $150,000 to $300,000 per year could be incurred. Materials which are already reaching the brittle book stage could sustain irremediable damage; current replacement cost per volume is $50.00. If only 5,000 volumes a year are pushed into the unusable category of brittleness by environmental extremes, estimated replacement costs of $250,000 could be incurrend yearly, per facility.

CONTROL OF TEMPERATURE

Damage caused by heat

In chemical systems the rate of reaction doubles for each 10°C that temperature rises. This is known as Arrhenius's Law. Paper is a complex chemical system tending toward its most stable form—carbon dioxide and water--and although most paper never reaches this completely "burned" state, an intermediate, brittle, state of oxycellulose is often reached. This slow degradative process has been called by Feller (6) "Mother Nature's Book Burning."

Paper however does not follow the Arrhenius equation exactly; Barrow's study (7) found paper reaction rates to change 7.5 times for each 20°C of temperature change. Table 1, taken from Smith (8) and simplified by Feller, presents a graphic display of the importance of this complicated temperature dependent reaction rate for paper.

Table I
Effect of Storage Temperature on Paper Impermanence
(R.D. Smith)

Average Storage Temperature F	Diff. from 68 F (in F)	Paper Half-Life (in years)	Average Storage Temperature C	Diff. from 20 C (in C)
140	+72	1	60	+40
122	+52	4.1	50	+30
104	+36	18	40	+20
95	+27	40	35	+15
86	+18	88	30	+10
77	+9	204	25	+5
72.5	+4.5	320	22.5	+2.5
68	-	490	20	-
63.5	-4.5	760	17.5	-2.5
59	-9	1,200	15	-5
50	-18	3,100	10	-10

Table II, taken from Smith (8) extends the work on paper degradation rates by adding the level of inherent acidity in the paper to the equation. As can be seen, the lower the pH (or the higher the acid content) the more rapidly the paper becomes unusable.

Table II
Action of pH and Temperature on Paper
Half-Life (in years)

	pH		
Temperacure (°F.)	6.0	5.0	4.0
	Cold Water pH		
68	100	10	365*
72.5	65	6.5	240
77	42	4.2	150
86	18	1.8	66
95	8.2	0.82	30
104	3.7	0.37	17

* Figures in this column are given in days.

The importance of this table lies in the fact that research done by the staff of this office indicates that for materials currently in off-campus housing--these materials should be representative of other materials awaiting rehousing-- 44% have a current pH value of 4.1-5.0. An additional 46% have pH values of 4.0 or below. Since most of these materials are bound volumes, the degradative process is somewhat slower than the table, based on single pages, would indicate.

Temperatures do not have to remain elevated for long periods of time to cause such degradation, as Wessel (2) notes "High temperature exposures of paper, even for short periods, cause yellowing and brittleness." In addition to the direct action of heat on the paper fibers, indirect or secondary damage occurs. Cycles of temperature change--regardless of extremes—at the ambient levels in California can damage paper and photographic records by expanding and contracting the material. The glues holding the spines of bound books together are especially susceptible to damage; heat also drives off water and plasticizers from cellulose based products. Loss of water, solvents and plasticizers often destroy paper, leather, fabrics, plastics and other substances used in library materials. Temperatures above 70°F also promote the rapid growth of mold under favorable humidity conditions.

Standards for temperature control

There is universal agreement that the colder most library materials are kept the longer they will survive (See Table I). However, for the comfort of patrons and staff, temperatures are often maintained higher than accepted material preservation practice would call for. Maintenance of 65°F ± 3° year around would provide some measure of protection to the library material while providing a suitable working environment for patrons and staff.

Banks (9), however, recommends 60°F ± 5° for book storage areas. The new storage facility at the Newberry Library in Chicago will be maintained at this level.

Effects of un-controlled temperature: estimated costs

As noted above, many of the materials to be housed in the Regional Facilities are already in a damaged condition. Further damage will occur exponentially in the presence of uncontrolled environmental factors. If the estimated 2% of stored materials which now have pH values of 3 are further damaged by temperature cycles and extremes, the replacement cost could exceed $3,000,000 (estimate based on 3,000,000 volumes with average replacement cost $50.00).

CONTROL OF HUMIDITY

Damage caused by variation in humidity

Relative humidity, the ratio of the actual water vapor content of air to its total capacity at a given temperature, has the greatest influence on preservation of library materials. The relationship between relative humidity, absolute humidity, and temperature is given in Table III.

Table III

Temperature		Absolute Humidity In Grams of H_2O/Kilograms Air		
°C	°F	RH = 20%	RH = 60%	RH = 100%
0	32	0.38	2.28	3.82
20	68	1.43	8.69	14.61
40	104	4.55	28.30	48.64
60	140	12.50	83.55	152.45

From Wessel (2)

As temperature increases the air can carry more water vapor in g/kg at any given relative humidity. As air cools it looses the capacity to carry water vapor and the excess precipitates as "dew" or condensation. Objects inside a building, such as books, may be cooler than the ambient air and may develop a film of condensed water vapor on their exteriors. Such an occurrence can easily damage library materials which are commonly bound in hygroscopic or water-loving substances such as starch-filled cloth, leather, or vellum. This water vapor also provides the hydrogen ions that react with airborne pollutants to form acids such as carbonic, nitric, and sulfuric; these acids are a major factor in continued degradation of library material. Equally important is the movement of water within library material caused by fluctuations in temperature or humidity. This interstitial water causes soluble salts and acids to move through the material and in this manner "good" paper which is placed next to deteriorated paper may be damaged by acid migration from the poor paper to the good (2).

Since library materials are hygroscopic, they can pick up high percentages of their weight in water. Although such occurrences rarely happen except in flood conditions large water loads can be abstracted from the air by materials such as paper. Such water provides the chemical medium for degradation reactions, as noted above, and it may also dissolve materials such as dyes and adhesives. In addition, excess humidity may cause some other materials to become soluble adhesives which stick pages and books together almost beyond separation.

Extremes of humidity in the low direction can cause paper, leather, and vellum to become brittle and crack; adhesives break apart and literally cut

books apart. Wooden boards in the covers of older books may warp sufficiently to tear the covers from the book.

Above approximately 60% relative humidity mold grows at temperatures beginning as low as 40°F. At humidity levels above 70% the growth of mold is almost a certainty as temperatures exceed 68°F. Table IV indicates the average monthly humidity in the Bay Area and the Los Angeles Basin.

Table IV
Mean Relative Humidity for San Francisco and Los Angeles Areas

Month	San Francisco Area	Los Angeles Area
January	77	58
February	78	62
March	75	63
April	78	65
May	78	67
June	77	70
July	79	68
August	80	69
September	76	65
October	76	65
November	76	54
December	80	55

From Wessel (2)

Standards for humidity control

All authorities in the preservation field agree that a relative humidity of 50% is necessary for the preservation of library materials (2, 5, 7, 8, 9, 10, 11, 12). Although this figure is high for the storage of film and phonodiscs it is the best compromise and should be considered an upper limit. A lower limit of 35% can be tolerated by photographic film but not by leather or vellum bindings.

Effects of uncontrolled humidity on library material: estimated costs

Although one cannot predict the amount of damage that might occur to a given volume or manuscript in the absence of humidity controls, one can be aware of the costs of repair. Rebacking of a leather bound book made brittle by too little humidity is estimated to cost $75 - $125 per volume. Rebinding of a typical leather bound volume damaged by binding boards warped by humidity is estimated at $250.00. If only 4% of the material in a regional facility became infested with mold, fumigation costs alone are estimated at $300,000.

CONCLUSION

It is not possible to say, a priori, that a given temperature or humidity will damage a given volume to a certain dollar amount. It is possible to state that the combined effects of uncontrolled environmental factors upon library materials is great. Based on the UC insured value, each Regional Facility at capacity is to house materials valued in excess of $281,250,000. The estimate for environmental protection of this tremendous investment is $1,160,000 or 1/243 of the insured value. We need only lose 12,000 volumes to atmospheric acid, high temperature or excessive humidity to completely offset the cost of the control system. Damage of $.39 per volume over any time span would also offset the cost of environmental control. Conversely, total environmental control can be achieved for a one-time capital outlay of $.39 per volume or $.02 per volume per year over the estimated 20 year life span of the equipment. Table V summarizes the costs estimated in previous sections. It seems likely that the cost of damage incurred by materials housed in an uncontrolled environment could easily offset any savings realized by not making the environmental controls available.

Table V
Estimated Costs of Environmental Damage
Two Regional Housing Facilities
3,000,000 volumes each

Environmental Variable	Damage Caused by	Estimated Percentage of Collection Which Might be Affected	Estimated Damage Cost
Atmospheric Pollutants	Particulate Matter	100%	$360,000*
	Acid Forming Gases	100%	$300,000 - 600,000*
Temperature	Extremes of Heat	2%**	$6,000,000
Humidity	Mold	4%	$600,000
	Direct Damage	?	$75-$125 per volume

* Yearly recurring cost.

** Precentage of stored collection currently in fragile condition.

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